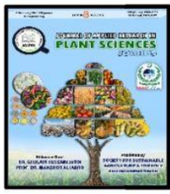
J. Appl. Res Plant Sci. Vol. 5(1), 105-110, 2024, https://doi.org/10.38211/joarps.2024.05.220

Research Article

OPEN ACCESS



Available on https://www.joarps.org
Journal of Applied Research in Plant Sciences
(JOARPS)
ISSN: 2708-3004 (Online), 2708-2997 (Print)

Effect of Foliar Application of Phosphorus and Zinc on Biometric and Quality Attributes of Fodder Maize in Calcareous Saline-Sodic Soils

Abdur Rehim[1], Namra Khurshid[1], Qurat-Ul-Ain Raza[1], Muhammad Amjad Bashir[1,2,3*], Hifsa Khurshid[4], Hafiz Muhammad Ali Raza[1],[3]

[1]Department of Soil Science, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan 60800 Pakistan
[2]Department of Agronomy, Engro Fertilizers Ltd. Lahore, 54600, Pakistan
[3]College of Agriculture, University of Layyah, Layyah, Pakistan
[4]Muhammad Nawaz Sharif University of Engineering and Technology, Multan 60800, Pakistan.
*Corresponding Authors Email; amjad.bashir941@gmail.com

Article Received 21-09-2023, Article Revised 10-10-2023, Article Accepted 02-12-2023.

Abstract

The hot climate is the major reason to promote salt salinization and sodication, which retards the crop productivity. The increase in salt-affected soils is adversely affecting worldwide productivity. The antagonistic effect among P and Zn causes nutrient deficiency and increases under saline conditions. The present study aimed to identify the targeted influence of foliar application of P and Zn on maize biometric and fodder quality parameters under saline-sodic conditions. The experiment was based on three P (0, 1, 2, 2.5%) and Zn levels (0, 1, and 1.5%), with three replications. The study showed that P concentration in maize was improved significantly with Z_1P_1 (51.0%) application, followed by Z_0P_2 (33.15%) and $Z_{1.5}P_{2.5}$ (28.0%). The Zn concentration enhanced with Z_1P_0 (91.73%), followed by Z_0P_1 (84.45%) and $Z_{1.5}P_1$ (84.18%). Nitrogen concentration improved with $Z_{1.5}P_{2.5}$ (39.84%). Total mineral contents were increased with $Z_{1.5}P_2$ (156.71%), followed by Z_0P_1 (142.64%) and Z_0P_2 (141.99%). Crude protein concentration was improved in $Z1_{.5}P_1$ (39.92%), followed by Z_0P_2 (11.92%). Crude fat percentage was increased with $Z_0P_{2.5}$ (51.89%), followed by Z_0P_1 (34.91%) as compared to Z_0P_0. The study concludes that foliar application of P and Zn in saline-sodic conditions helps retard the negative impacts of salts on biometric and quality parameters of maize fodder.

Keywords: Crude fat, fodder quality, nutrient, protein, salinity

Introduction: Salinity and sodicity have adversely affected about 33% of the irrigated land and 25% of the total land globally (Mohanavelu *et al*., 2021). Being a climatically vulnerable country, Pakistan is also bearing the effects of saline-sodicity, hindering plant growth and development. High levels of water-absorbing salts, sodium, and pH are a few of the features of saline-sodic land that directly or indirectly affect seed germination plant vegetative and reproductive growth (Abdul Qadir *et al*., 2022; Ahmed et al., 2018). Furthermore, owing to the ionic configuration of saline-sodic areas, which reduces soil permeability, the groundwater salts also reach the soil surface and induce more salinity (Mohanavelu *et al*., 2021). Various strategies such as physical, chemical, and biological remediation, the addition of gypsum, sulphur, manure, compost, microbes, zeolites, and on-farm seed priming are being adopted to decrease the deleterious effects of saline-sodic lands (Abdul Qadir *et al*., 2022). Phosphorus (P) is the most important nutrient, after nitrogen, for plants in agriculture (Yadav *et al*., 2019), and the deficiency of P limits crop productivity. Salinity also reduces the P availability, and this salinity-induced P deficiency is also a kind of abiotic stress observed in salt-affected soils. Thus, it is a major challenge for scientists to tackle the reduced P availability in saline-based soils (Ahmed *et al*., 2018; Dey *et al*., 2021). Amongst the micronutrients, Zinc (Zn) is important for plants as it plays a significant role in plant growth and development, protein formation, metabolism, and chlorophyll (Raza, Bashir, Rehim, Jan, *et al*., 2021). More than 50% of the soils are Zn deficient, and plants cultivated in saline soils also show deficiency symptoms globally (Al-Zahrani *et al*., 2021). Zn deficiency can lead to the accumulation of toxic ions sodium and chlorine. To overcome environmental constraints, scientists are inclined to apply micronutrients as a foliar spray to improve plant growth and development (Iqbal *et al*., 2018). Maize (*Zea* *mays* L.) is one of the major cereal crops due to its worldwide use for feeding humans and livestock. In Pakistan, it is the most important crop after wheat and rice, as it contributes 0.7% to GDP (Pakistan Bureau of Statistics, 2023). It is a C4 plant, thus an efficient converter of absorbed nutrients to food (Raza, *et al*., 2021). Moreover, the crop is also known as a "miracle crop" and "queen of cereals" due to its high potential use in the community (Suganya *et al*., 2020). In addition, the performance and health of animals is highly dependent upon the quality and nutritional status of fodder. A good fodder contains protein content, soluble carbohydrates, mineral nutrients, and crude fiber (Manoj *et al*., 2021). Therefore, it is important to produce and provide quality diets to animals. Considering this background, the present study was exhibited to understand the interaction of P and Zn under saline-sodic soil conditions. As per knowledge published, the studies indicate that P and Zn have antagonistic effects under saline-sodic conditions. To overcome this issue, the current study was the need of time to reduce the P and Zn deficiency in fodder crops. It was hypothesized that foliar application of both nutrients will reduce their interaction (antagonistic) in soil and help to enhance P and Zn concentration in maize fodder. The objectives of the study were (1) to determine the impacts of foliar P and Zn application on biometric, nutritional, and quality attributes of fodder and (2) to identify the suitable fertilizer dose for maize productivity under saline soil conditions (3) to determine how much-supplemented P and Zn could alleviate inhibitory salinity effects on maize fodder.

Materials and methods

Study site: The experiment was carried out at the Research Farm (30.2º E, 71.5º N) of the Department of Soil Science, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Pakistan. The Multan city occupies an area of 3,721 square Kilometers, and the River Chenab is the natural and primary source to irrigate agricultural lands. The land is highly productive, whereas the climate falls under semi-arid conditions. The maximum recorded temperature is 54℃, and the lowest is 4.5℃. Whereas the mean annual rainfall is 186 millimeters (Raza, Bashir, Rehim, Jan, *et al*., 2021). Soil samples were collected from the field from a depth of 0-15 cm. The soil samples were air-dried, sieved, and analyzed for all the physio-chemical properties including EC (4.41 dS m-1), pH (8.89), sand (50.5%), silt (26.2%), clay (24.1%), organic matter (0.66%), calcium carbonate (6.89%), total N (0.04%), extractable P (0.02%), and extractable Zn (0.01%).

Experimental design: For field preparation, pre-irrigation was maintained for five days to attain an optimal soil moisture level, followed by ploughing. Hard pans and soil clods were crushed using a disc harrow. Fine ridges were prepared, maintaining suitable row-to-row (75 cm) and plant-to-plant distance (9 cm), whereas the plot size was 12 m^2. The recommended seed rate of maize hybrid Pak-Afgoi (SG 2002, Chattha Seed Corporation, Pakistan), i.e., 75-100 kg ha^{-1}, was used in the experiment (Ayub *et al*., 2003). Plants were irrigated continuously during the complete growth period to maintain the optimum moisture level. All the crop management and cultural measures were abided by strictly. Weeds were eradicated manually. The recommended dose of NPK (140:50:60 kg ha^{-1}) was applied in all plots. PK was applied at sowing whereas N was applied in 3 splits, i.e., sowing, 20 and 40 days after germination. The source of NPK was urea (46% N), diammonium phosphate (DAP, 46% P_2O_5), and muriate of potash (MOP; 60% K_2O; manufactured by FFC, Pakistan). The experiment comprises twelve treatments, including three P levels (0, 1, 2, 2.5%) and three Zn levels (0, 1, and 1.5%). The source of P and Zn was KH_2PO_4 (22.76% P) and $ZnSO_4$ (33% Zn) were used. Foliar application of P and Zn was carried out 30 and 40 days after sowing, respectively. Treatments were replicated thrice in a randomized complete block design.

Plant Analysis

Biometric attributes: All the plants from each plot were counted. Biometric parameters, including fresh weight (kg), dry weight (kg), and plant height (cm), were measured using a weighing balance and measuring tape.

Nutritional attributes: The plant samples were air-dried and then oven-dried until constant weight was achieved. Afterward, the samples were ground and digested using a di-acid mixture (HNO_3: $HClO_4$:) in 2:1 ratios. Ground samples were added to the digestion flasks with HNO_3 and left overnight. Afterward, samples were heated using a hot plate at 125° for 1 h, and HNO_3 was added until a colorless solution was obtained. These samples were used for further analysis, including P (%), Zn ($\mu g g^{-1}$), and N (%) concentration. All the chemicals used in the experiment were of analytical grade. N was estimated using Kjeldhal method (Kjeldahl, 1883), P was determined following colorimetric method using spectrophotometer (McGeorge, 1954), Zn was determined using atomic absorption spectrophotometer (Thermo Scientific 3000 Series, Waltham, MA, USA).

Fodder quality attributes: The fodder quality parameters, including total minerals (using muffle furnace), crude protein (Kjeldahl method), and crude fat (soxhlet method), were analyzed (Harrow, 1950).

Statistical analysis: Data were analyzed using the Mean values (±SD) for all physic-chemical and fodder quality attributes were calculated. Magnitude of variation amongst treatment groups in these attributes was ascertained through ANOVA with Least Significant Difference (LSD), using a completely randomized design. Duncan's multiple range test, where necessary, was implied in order to detect differences between mean values.

Results and discussion: It was designed with the objective to analyze the effect of foliar application of P and Zn on certain physicochemical and fodder quality attributes of maize in calcareous saline-sodic soils of Punjab, Pakistan. Owing to the paucity of literature on maize, comparisons of the present study are being made with those on other crops as well.

Biometric attributes: The data regarding the biometric attributes of maize fodder (fresh weight, dry weight, and plant height) revealed that all the parameters showed significant differences among different rates of foliar application of P and Zn. However, the interaction of P and Zn showed non-significant results, as shown in Table 1.

Table1. Effect of foliar application of phosphorus and zinc on biometric attributes of maize fodder.
All the values given are means±standard deviation (n=3), and the lowercase letters indicate that significant difference among means.

Treatments	**Fresh Weight (kg)**	**Dry Weight (kg)**	**Plant Height (cm)**
Z_0P_0	2.1 ± 0.2 a-c	1.0 ± 0.0 a-c	128.1 ± 5.42 a-c
Z_0P_1	2.9 ± 0.4 a	1.3 ± 0.6 a	159.1 ± 9.69 a
Z_0P_2	2.5 ± 0.7 ab	1.3 ± 0.2 a-c	130.7 ± 18.9 a-c
$Z_0P_{2.5}$	1.7 ± 0.1 b-d	0.8 ± 0.1 a-c	130.0 ± 12.01 a-c
Z_1P_0	1.3 ± 0.3 cd	0.6 ± 0.2 a-c	137.6 ± 6.05 a-c
Z_1P_1	1.6 ± 0.1 b-d	0.7 ± 0.1 a-c	141.0 ± 7.67 a-c
Z_1P_2	1.9 ± 0.1 a-c	0.9 ± 0.1 ab	145.8 ± 9.92 ab
$Z_1P_{2.5}$	1.0 ± 0.1 cd	0.5 ± 0.1 a-c	136.6 ± 23.84 a-c
$Z_{1.5}P_0$	0.7 ± 0.0 d	0.3 ± 0.0 a-c	109.8 ± 17.99 bc
$Z_{1.5}P_1$	0.8 ± 0.1 d	0.4 ± 0.1 bc	104.2 ± 4.42 c
$Z_{1.5}P_2$	1.0 ± 0.9 cd	0.2 ± 0.0 c	107.5 ± 7.51 c
$Z_{1.5}P_{2.5}$	0.6 ± 0.0 d	0.9 ± 0.0 c	105.8 ± 5.95 c

Furthermore, plant fresh weight was highest in Z_0P_1 (34.27%) followed by Z_0P_2 (18.78%) respectively. Plant dry weight increased significantly in Z_0P_1 (28.38%) followed by Z_0P_2 (26.07%) in comparison with control. Plant height was also increased with Z_0P_1 (24.21%) followed by Z_1P_2 (13.85%) in comparison with control. It might be due to osmotic stress and ion toxicity, which reduces the germination rate and inhibits early seedling growth. The soils having high pH and sodic conditions are poor in soil structure and water infiltration, which reduces plant growth, inhibits nutrient uptake, and results in low crop yield (Zhang *et al*., 2019).

Chemical attributes: The results indicate that varying rates of P and Zn foliar application, either applied alone or in combination with each other, turn out to be highly significant ($P \leq 0.01$) for all chemical attributes (Table 2).

Table 2: Effect of foliar application of phosphorus and zinc on chemical attributes of maize fodder

Treatments	**Phosphorus Concentration (%)**	**Zinc Concentration (μgg^{-1})**	**Nitrogen Concentration (%)**
Z_0P_0	0.197 ± 0.001 h	34.46 ± 2.08 e	1.69 ± 0.05 cd
Z_0P_1	0.208 ± 0.002 g	63.56 ± 0.85 ab	2.36 ± 0.01 a
Z_0P_2	0.266 ± 0.001 b	44.85 ± 1.93 d	1.94 ± 0.01 b
$Z_0P_{2.5}$	0.222 ± 0.001 e	33.97 ± 1.31 e	1.80 ± 0.01 bc
Z_1P_0	0.231 ± 0.001 d	66.07 ± 1.42 a	1.66 ± 0.01 cd
Z_1P_1	0.302 ± 0.001 a	54.11 ± 0.95 c	1.80 ± 0.01 bc
Z_1P_2	0.223 ± 0.002 e	61.17 ± 1.01 b	1.80 ± 0.01 bc
$Z_1P_{2.5}$	0.212 ± 0.001 f	52.79 ± 1.34 c	1.94 ± 0.01 b
$Z_{1.5}P_0$	0.221 ± 0.001 e	51.32 ± 1.20 c	1.54 ± 0.14 de
$Z_{1.5}P_1$	0.222 ± 0.001 e	63.47 ± 1.19 ab	2.36 ± 0.01 a
$Z_{1.5}P_2$	0.222 ± 0.001 e	43.44 ± 2.15 d	1.40 ± 2.72 e
$Z_{1.5}P_{2.5}$	0.256 ± 0.001 c	38.82 ± 1.43 e	1.54 ± 0.14 de

All the values given are means±standard deviation (n=3), and the lowercase letters indicate that significant difference among means.

P concentration in plants was significantly improved with the application of Z_1P_1 (51.0%), followed by Z_0P_2 (33.15%) and $Z_{1.5}P_{2.5}$ (28.0%) as compared to Z_0P_0. It might be associated with the foliar application of fertilizers where P enters into the leaf stomata and hydrophilic pores, thus contributing in increasing the plant nutrient availability (Rafiullah *et al*., 2021). Moreover, Zn concentration was improved with the application of Z_1P_0 (91.73%), followed by Z_0P_1 (84.45%) and Z_1P_0 (84.18%) in relation to control. N concentration was also increased with Z_0P_1 and $Z_{1.5}P_{2.5}$ (39.84%) as compared to Z0P0. It shows that increasing the rate of P reduces the concentration of Zn and vice versa (Korkmaz *et al*., 2021).

Quality attributes: Regarding all the quality parameters of maize fodder (total mineral, crude proteins, and crude fat), all the attributes are significantly ($P \leq 0.05$) higher with different levels of P and Zn foliar application either applied alone or in combination with each other. A highly significant ($P \leq 0.01$) increase was noticed for all attributes of Zn-P interactions. Total mineral content was increased with $Z_{1.5}P_2$ (156.71%), followed by Z_0P_1 (142.64%) and Z_0P_2 (141.99%) as compared to Z_0P_0 (Figure 1).

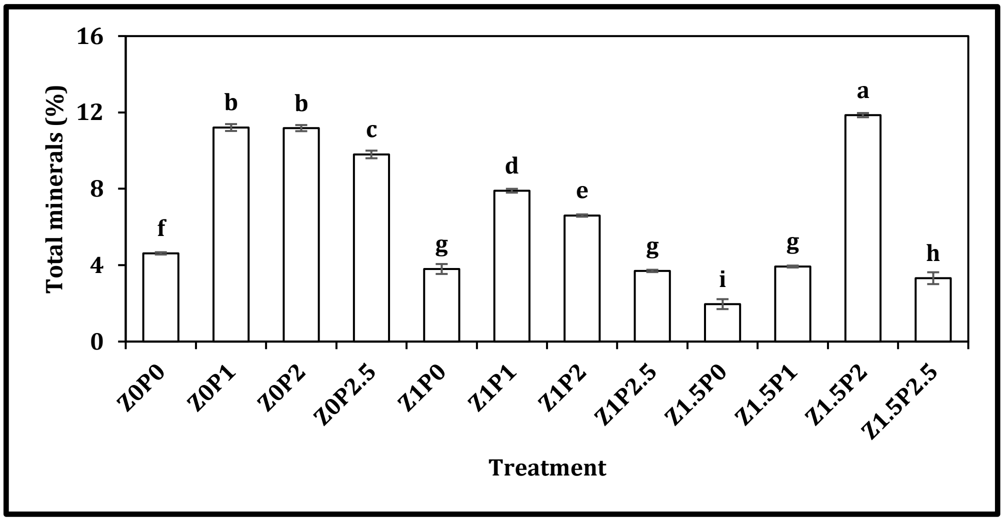


Figure 1. Effect of foliar application of phosphorus and zinc on total mineral percentage of maize fodder. All the values given are means±standard deviation (n=3), and the lowercase letters indicate a significant difference among means.

The application of Zn and P also influenced crude protein percentage. The highest crude protein concentration was observed in $Z_{1.5}P_1$ (39.92%), followed by $Z_1P_{2.5}$ and Z0P2 (11.92%) as compared to Z0P0 (Figure 2).

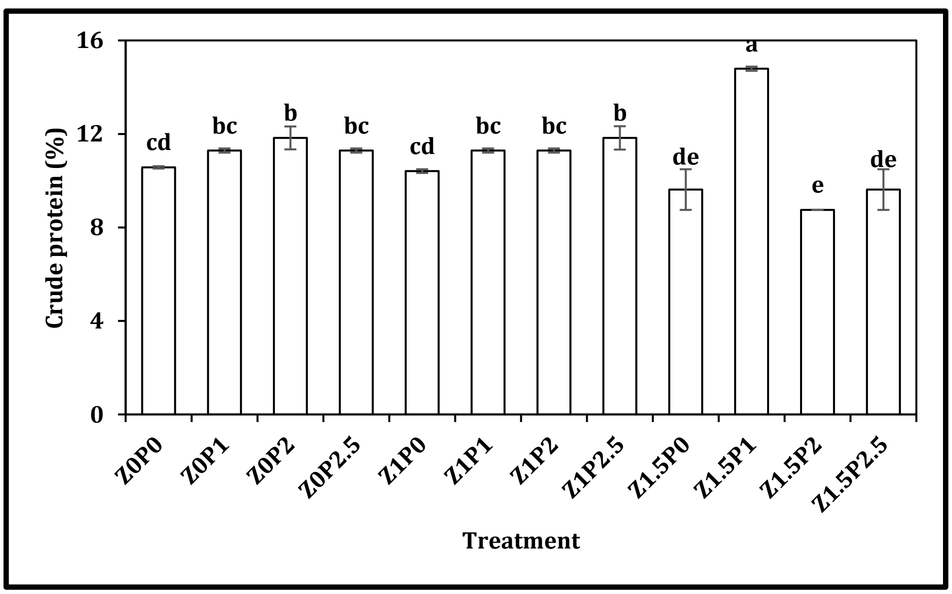


Figure 2. Effect of foliar application of phosphorus and zinc on crude protein percentage of maize fodder. All the values given are means±standard deviation (n=3), and the lowercase letters indicate a significant difference among means.

Crude fat percentage was increased with $Z_0P_{2.5}$ (51.89%), followed by Z_0P_1 (34.91%) as compared to Z_0P_0 (Figure 3).

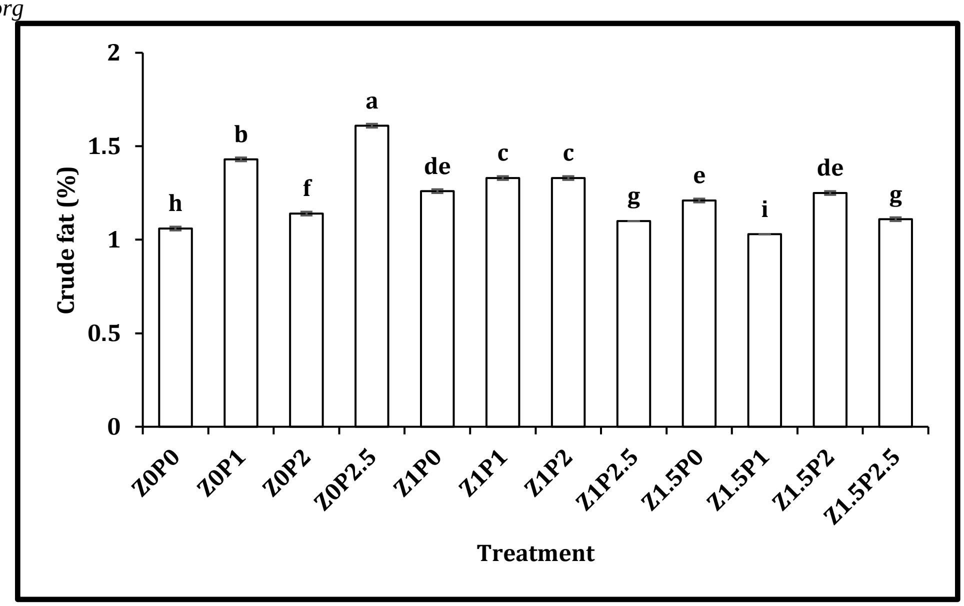


Figure 3: Effect of foliar application of phosphorus and zinc on crude fat percentage of maize fodder. All the values given are means±standard deviation (n=3), and the lowercase letters indicate a significant difference among means.

It has been reported that foliar application of nutrient fertilizers on maize plants results in rapid absorption and utilization of nutrients. Thus, it contributes to plant metabolic activities and shows positive impacts on maize plants (Brankov *et al*., 2020). The increased crop yield might be due to the quick absorption and assimilation of P with foliar application (Rafiullah *et al*., 2021).

Conclusion: In a nutshell, the present study reveals that the quality attributes (total mineral, crude proteins, and crude fat) and the chemical attributes (P, Zn, and N concentrations) of maize fodder are significantly affected by foliar application of P and Zn in saline-sodic soil. However, no such effect of foliar application was noticed for biometric attributes (fresh weight, dry weight, and plant height). Furthermore, the study also emphasizes the role of foliar application in saline-sodic lands. Future horizons require a broad-scale study on similar patterns coupled with climatological data of field area to attain optimal results of foliar application and optimal concentrations of P and Zn for saline-sodic areas. Moreover, a long-term study is required to identify its impact on soil properties and plant growth. Furthermore, the effects of this high-quality fodder on animals can also be studied in the future.

Funding

This study has not received any funding.

Declaration of Competing Interest

The authors declare no conflict of interest.

References

Abdul Qadir, A., Murtaza, G., Zia-ur-Rehman, M., & Waraich, E. A. (2022). Application of gypsum or sulfuric acid improves physiological traits and nutritional status of rice in calcareous saline-sodic soils. Journal of Soil Science and Plant Nutrition, **22**(2), 1846-1858.

Ahmed, K., Qadir, G., Nawaz, M. Q., Saqib, A. I., Rizwan, M., Zaka, M. A., ... & Bashir, M. A. (2018). Integrated phosphorus management improves production of rice–wheat cropping-system under salt affected conditions. International Journal of Plant Production, **12**, 25-32.

Al-Zahrani, H. S., Alharby, H. F., Hakeem, K. R., & Rehman, R. U. (2021). Exogenous application of zinc to mitigate the salt stress in Vigna radiata (L.) Wilczek—Evaluation of physiological and biochemical processes. Plants, **10**(5), 1005.

Ayub, M., Ahmad, R., Nadeem, M. A., Ahmad, B., & Khan, R. M. A. (2003). Effect of different levels of nitrogen and seed rates on growth, yield and quality of maize fodder. Pakistan Journal of Agricultural Sciences, **40**, 140-143.

Brankov, M., Simić, M., Dolijanović, Ž., Rajković, M., Mandić, V., & Dragičević, V. (2020). The response of maize lines to foliar fertilizing. Agriculture, **10**(9), 365.

Dey, G., Banerjee, P., Sharma, R. K., Maity, J. P., Etesami, H., Shaw, A. K., ... & Chen, C. Y. (2021). Management of phosphorus in salinity-stressed agriculture for sustainable crop production by salt-tolerant phosphate-solubilizing bacteria—A review. Agronomy, **11**(8), 1552.

Harrow, B. (1950). Laboratory manual of biochemistry.

Iqbal, M. N., Rasheed, R., Ashraf, M. Y., Ashraf, M. A., & Hussain, I. (2018). Exogenously applied zinc and copper mitigate salinity effect in maize (Zea mays L.) by improving key physiological and biochemical attributes. Environmental Science and Pollution Research, **25**, 23883-23896.

Bremner, J. M., & Mulvaney, C. S. (1983). Nitrogen—total. Methods of soil analysis: part 2 chemical and microbiological properties, **9**, 595-624.

Korkmaz, K., Akgün, M., Özcan, M. M., Özkutlu, F., & Kara, Ş. M. (2021). Interaction effects of phosphorus (P) and zinc (Zn) on dry matter, concentration and uptake of P and Zn in chia. Journal of Plant Nutrition, **44**(5), 755-764.

Manoj, K. N., Shekara, B. G., Sridhara, S., Jha, P. K., & Prasad, P. V. (2021). Biomass quantity and quality from different year-round cereal–legume cropping systems as forage or fodder for livestock. Sustainability, **13**(16), 9414.

McGeorge, W. T. (1954). Diagnosis and Improvement of Saline and Alkaline Soils: By Staff of US Salinity Laboratory, Agriculture Handbook No. 60 US Dept. Agric., Supt. Documents, US Government Printing Office Washington 25, DC, 1954, 160 pages, $2.00.

Mohanavelu, A., Naganna, S. R., & Al-Ansari, N. (2021). Irrigation induced salinity and sodicity hazards on soil and groundwater: An overview of its causes, impacts and mitigation strategies. Agriculture, **11**(10), 983.

Iqbal, A., Shafi, M. I., Rafique, M., Zaman, M., Ali, I., Jabeen, A., ... & Jiang, L. (2023). Approaches for Using Bio-fertilizers as a Substitute for Chemical Fertilizers to Improve Soil Health and Crop Yields in Pakistan. In Biofertilizers for Sustainable Soil Management (pp. 89-118). CRC Press.

Raza, H. M. A., Bashir, M. A., Rehim, A., Jan, M. U. H. A. M. M. A. D., Raza, Q. U. A., & Berlyn, G. P. (2021). Potassium and zinc co-fertilization provide new insights to improve maize (Zea mays L.) physiology and productivity. Pak. J. Bot, **53**(6), 2059-2065.

Suganya, A., Saravanan, A., & Manivannan, N. (2020). Role of zinc nutrition for increasing zinc availability, uptake, yield, and quality of maize (Zea mays L.) grains: An overview. Commun. Soil Sci. Plant Anal, **51**(15), 2001-2021.

Yadav, V., Karak, T., Singh, S., Singh, A. K., & Khare, P. (2019). Benefits of biochar over other organic amendments: Responses for plant productivity (Pelargonium graveolens L.) and nitrogen and phosphorus losses. Industrial Crops and Products, **131**, 96-105.

Zhang, J., Jiang, X., Xue, Y., Li, Z., Yu, B., Xu, L., ... & Cui, Z. (2019). Closing yield gaps through soil improvement for maize production in coastal saline soil. Agronomy, 9(10), 573.